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RADAR TARGET SIGNATURE PROGRAM PERFORMANCE SPECIFICATION.(U)
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This report is a Program Performance Specification (PPS) for a digital computer program that calculates the radar signatures of ships. The PPS will be used to guide the program through three development phases and acceptance testing. The primary objectives of the program are accuracy, flexibility of application, ease of modeling, and portability. The ship is modeled by identifying and defining all the geometrical shapes which cause radar scattering and coherently adding the signals from all of the appropriate ones. The program will handle far-field, near-field, and bistatic geometries; antenna patterns; radar absorbing material; and high range resolution effects.

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CONTENTS

Program Performance Specification for a Radar Signature Model

1. SCOPE

This specification details the performance requirements for a digital model of the radar signature of ships.

1.1 Purpose

This Program Performance Specification (PPS) shall describe in detail the requirements necessary to design, test, maintain and evolve the required digital processor program. The PPS shall be the controlling document for procurement and assessment of satisfactory completion of the program and documentation of the program. The requirements shall be sufficient to provide signature data to users who need total radar cross-section (RCS) both far and near field, high range resolution signature, synthetic aperture radar (SAR) signature, and glint (angular scintillation) signature. The requirements shall be compatible with the capabilities of moderate-sized general purpose scientific computers.

1.2 Mission

The users of this program will be designing radars, simulating radar performance, evaluating radar performance, designing ships, evaluating ship signature suppression, etc. A radar designer must have a means of finding the particular target signature characteristics from the particular viewpoint from which the particular radar system must be optimized. Anti-ship missile simulations require detailed ship signature data so that seeker performance can accurately be

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predicted which in turn allows the determination of where the missile will go with respect to the ship. Radar systems designed for specific (or general) targets sometimes need to be evaluated for other applications than the intended (or usual) ones, and therefore require target specific signature data. Naval architects may have ship signature specifications to satisfy which require the testing of various hull-super-structure configurations to meet specification and balance other factors. The program may be used to evaluate various signature suppression techniques against each other or to evaluate their overall effect.

Some users of this program will incorporate a subset of the program into programs of their own, wherever radar signature data is needed. In particular, anti-ship missile simulations may have the model embedded in them, so as to provide RCS for missile search and acquisition, glint and RCS for track, and RCS for track, and RCS for fuze function. Other users will employ one of the drivers (main programs) provided by this signature program.

1.3 Scope

This specification covers a collection of digital computer programs and associated documentation that will enable technically trained personnel to (1) develop geometric models of ships suitable for use in the target signature program, (2) run the various driver programs to obtain RCS, glint and image data for the conditions they need, and (3) incorporate the signature program into programs of their own for their own purposes. Three levels of the signature model programs are specified: (1) initial - a configuration which supports a useful subset of objectives; (2) minimum - supports all the objectives in a way which reduces the effort required to get signature data to a practical level and provides input error checking capability; (3) enhanced - supports all the objectives in a

way which minimizes effort and human error while allowing maximum program flexibility.

This specification is intended to guide the development and testing of a set of programs that will enable the accurate calculation of ship radar signatures. Besides accuracy, the primary objectives are flexibility of application, ease of ship modeling and program portability. Secondary objectives are minimizing the cost of signature calculations, minimizing the size of the computer required, and providing graphs and printouts to aid in analysis and explanation.

1.3.1 Identification

The Target Signature Programs (TSP) are divided into three sets of programs called (1) the Geometric Target Modeler (GTM), (2) Target Signature Generator (TSG), and (3) Radar Aplication Drivers (RAD).

The GTM programs are further divided into two subsets: (1) Shape Parameter Generator (SPG), and (2) Shape Window Generator (SWG).

The TSG programs are divided into three subsets: (1) Model Data Initialization (MDI), (2) Target Signature Calculator (TSC), and (3) Signature Report Formater (SRF).

The RAD set is a collection of individual main programs.

1.3.2 Functional Summary

The GTM is used by the modeler to create shape data for the TSG. Beginning with ship data (either pictorial - drawings or photographs - or digitalized - developed for other purposes) the SPG calculates the required shape

parameters that describe the shapes from which the ship models are built. The parameters are then formatted into files for use by the MDI programs. These files are also the input for the SWG which calculates "windows" about the target through which each shape may be "seen" by a radar. These "windows" are formatted into files for the use of MDI.

The MDI programs, when called upon by a RAD program, read the shape parameter, shape window, and Radar Absorbing Material (RAM) files and put the data into arrays for use by the TSC. The TSC uses the target model data in the arrays to calculate the target signature for the conditions received from a RAD. When called by a RAD, a SRF program stores, prints, plots or analyzes the radar signature data calculated by the TSC.

The RAD programs are structured to provide signature data for a given application. The modeler selects (or writes) one for his purpose and provides it with radar and geometric data for input. See Figure 1.3.2-1.

2. APPLICABLE DOCUMENTS

American Standard Fortran, New York: American Standards Association, Inc., 1966.

American National Standard Programming Language FORTRAN, S3,9 - 1978, ANSI, 1430 Broadway, New York, N.Y.

Status Report of the GSPC, ACM SIGGRAPH, ACM, New York, 1977.

Modeling the Radar Angular Glint of an Aircraft Target, 17 April 1972, C. A. McGrew.

3. TARGET SIGNATURE PROGRAM REQUIREMENTS

This section defines and specifies all functional and performance requirements, plus all design constraints and standards necessary to ensure proper development and maintenance of the TSP.

3.1 General

The requirements section contains a general description of the TSP and detailed functional requirements for each of the major blocks of the program. Interfaces between the digital program, the input/output devices and human beings are identified and defined. Each major block of the TSP is defined with respect to its inputs, processing, and outputs.

3.2 Program Description

The TSP is basically designed to be run by itself without connection to any peripheral equipment. However, it is designed to function properly as an integral part of a radar simulation.

3.2.1 General Description

To get the radar signature of a target using the TSP, a geometric model of the target must be built using shapes from a set supported by the SPG, for which radar reflection formulas exist in the TSC. There are various types of target descriptions available to the modeler. A set of drawings from all orthogonal viewpoints of the exterior of a target would usually be sufficient data to generate a geometric model of a target. Complete, accurate sets of drawings are frequently unavailable, when photographs may be. A set of photographs generally from all quadrants would also permit satisfactory modeling of a target. A third

type of target description is an existing digital one. Such a description which preserves the target surface information, especially the curvatures, might be able to be converted into the input format of the SWG and MDI.

Once the target is modeled, one of the RAD programs may be selected to get the type of radar signature information needed. Radar data, such as frequency and polarization, are input to the program along with geometric data, such as radar position and path with respect to the target. The required signature data will be printed (plotted, punched, stored) for the user.

Since it is impossible to completely anticipate the needs of all users, provision is made for users to write their own RAD program. This will be necessary for those incorporating the TCP into simulations.

3.2.2 Peripheral Equipment Identification

This program interfaces with card readers, card punches, magnetic tape recorders, printers, plotters and interactive graphics devices. It is intended that, in so far as possible, the interfaces be manufacturer and device type independent.

3.2.3 Interface Identification

The TSP interfaces with the host digital computer operating system and Fortran library routines. Interfaces with card readers, card punches, magnetic tape recorders and line printers are through FORTRAN READ and WRITE statements. Interfaces with plotters and interactive graphics devices are through library routines which conform, as much as is feasible, to the Core System proposed by the Graphics Standard Planning Committee of the Association for Computing Machinery or to successor proposals (if any) or to the adopted standard (if any).

3.3 Functional Description

Section 3.3 contains the functional relationship of the TSP program with interfacing equipments and the functional relationship of the major functions of the TSP.

3.3.1 Equipment Descriptions

The following is a list of equipments which may be used by the TSP with the purpose and requirements of each.

3.3.1.1 Card Readers

Card readers may be used to acquire data from human beings or other programs. There are no special requirements.

3.3.1.2 Card Punches

Card punches may be used to provide a permanent record of small amounts of data, especially to accumulate data from many runs. There are no special requirements.

3.3.1.3 Magnetic Tape Equipment

Magnetic tape equipment may be used to provide intermediate time lengths and archival storage of large files. It may be used for short term storage only if disk storage is unavailable. Nine track, 1600 bpi EBCDIC, ANSII labelled format shall be used wherever possible.

3.3.1.4 Printers

Printers may be used to provide printed information to human beings. A minimum of 131 characters per line is required and no print file line may be longer than 131 printable characters.

3.3.1.5 Plotters

Plotters may be used to provide pictorial information about target model, scattering centers, radar images, signature chracteristics vs time, signature characteristics vs position, etc. There are no special requirements.

3.3.1.6 Graphic Tablet

Graphic tablets may be used for data entry in SPG. Accuracy must be 1 in 300 and resolution 1 in 1000.

3.3.2 TSP Input/Output Utilization Table

The TSP may use FORTRAN I/O logical units 1 through 49 (see Table 2.2.2-1).

3.3.3 TSP Interface Block Diagram

See Figure 3.3.3-1

TABLE 3.3.2-1, FORTRAN I/O LOGICAL UNIT NUMBERS

FORTRAN LOGICAL UNIT NUMBER	FORMATTED /UNFOR-MATTED	RECORD SIZE IN BYTES	RECORD SIZE IN WORDS	FILE		
				ORIGIN	USED	NAME
1	F	80	--	SPG	SPG	Shape Pictorial Data
2	F	80	--	SPG	SPG	Basic Shape Data
3	F	80	--	SPG	SWG,MDI	Shape Parameter Data
4	F	80	--	SWG	MDI	Shape Window Data
5	F	80	--	User	RAD	Run Parameters
6	F	133	--	SRF,RAD	---	Normal Print
7	F	80	--	SRF,RAD	---	Normal Punch
8	F	72	--	SRF,RAD	---	Run Summary
9	F	80	--	User	MDI	RAM Data File
10-19	F	Var.	--	SRF,RAD	---	Supplementary Print (Plot)
20-29	F	Var.	--	TSP	TSP	Storage
30-39	U	---	Variable	TSP	TSP	Storage
40-49	U	---	Variable	TSP	TSP	Local scratch

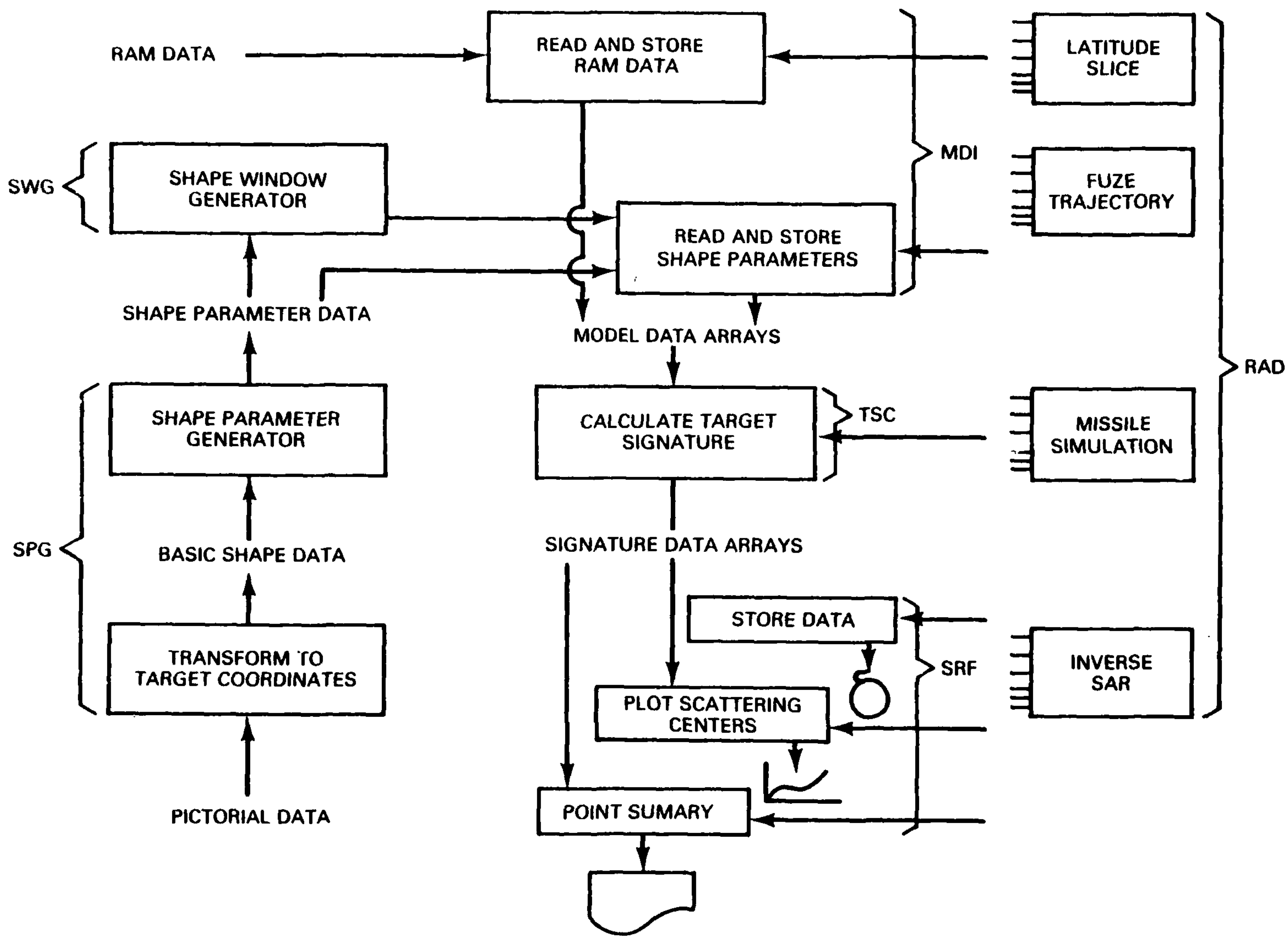

Figure 3.3.3-1 TSP INTERFACE BLOCK DIAGRAM

3.3.4 Program Interfaces

Any Radar Application Driver, whether one supplied in TSP or not, must interface directly with the MDI and TSC and most likely would interface with SRF. A RAD must call the MDI controller subroutine, specifying a valid logical unit number for the location of all data files required by TSC for the particular run. At any time when program control is in the RAD, new model data can be read in to replace the existing data. Whenever a sample radar signature is required, RAD must call TSC with parameters which specify the frequency, whether far-field is assumed, whether to use an antenna pattern, whether the receiver is pointing directly at the target, the receiver position, the receiver pointing direction, the receiver polarization E-vector, whether the transmitter is the same as the receiver (monostatic), transmitter location, transmitter pointing direction, transmitter polarization E-vector, whether range resolution is necessary, and range resolution data vector. If antenna patterns are to be used then existing dummy routines GAINR and GAINT must be replaced with ones supplied by the user. The total RCS, phase, orthogonal glints and range cell vector are returned from TSC as parameters as well as being stored in a COMMON block for use by SRF. If any of the signature reporting routines of the SRF are needed, they are called as needed with appropriate control parameters.

3.3.5 Function Description

A brief statement of purpose and a simplified functional diagram for each of the major TSC functions is given below.

3.3.5.1 Shape Parameter Generator

The purpose of the SPG is to provide the shape parameters (and shape modifications) that the TSC needs to calculate radar scattering information. Three different kinds of target description may be used. Each type of target description requires a different program to convert the target description into Basic Shape Data form consisting of, for each shape, a set of the coordinates of points on the shape, the type of shape and an arbitrary index number. These programs are called (1) Drawing Transform - for drawings, (2) Photograph Transform - for photographs, and (3) Digital Transform - for digitalized data. The Basic Shape Data is used by the Shape Transform to calculate the shape parameters and modifications which constitute, when all shapes are put together, the shape model of the target. See Figure 3.3.5.1-1.

3.3.5.2 Shape Window Generator

The purpose of the SWG is to save computer run time by calculating in advance the direction about the target where each scatterer has a significant cross-section and is not obscured by some other part of the target. The Shape Window Data which contains this information is optional and provides significant savings only where repeated use of the model is made, principally in simulations. See Figure 3.3.5.2-1.

3.3.5.3 Model Data Initialization

The purpose of the MDI is to read all model data from input files, organize it, check it, put it into COMMON blocks for use by the TSC, and print it as a record. The user need only specify the logical unit numbers of the

model data files as parameters of a subroutine call to MDI. See Figure 3.3.5.3-1.

3.3.5.4 Target Signature Calculator

The purpose of the TSC is to use stored model data to calculate the target signature characteristics for the geometrical and radar conditions supplied by the calling RAD Program. The TSC calculates reference vectors, selects the scattering centers to be summed, calculates the scattering matrix of each selected scatterer, uses radar polarization characteristics to calculate a complex number representation of the scattering, modify the phase of the scattering to account for the position of scatterer on the target, modifies the scattering complex number for near-field effects (if any), antenna patterns (if any), fade-in (out), RAM attenuation, and whether there is line-of-sight to scatterer. Sea surface reflected rays are added to the scatter list and all scattering complex numbers are summed (in range bins if radar is high-range-resolution type) for a target signature complex scattering number from which RCS and phase are calculated. The individual scattering complex numbers are combined in another way to calculate the phase front tilt called glint. See Figure 3.3.5.4-1.

3.3.5.5 Signature Report Formatter

The SRF subroutines put signature data in a form for users to understand and have for documentation. Some of these routines (when called by a RAD) print, plot, or make files of basic signature data. Others provide analyses of signature data such as finding the largest scatterers or applying an FFT to a RCS history. See Figure 3.3.5.5-1.

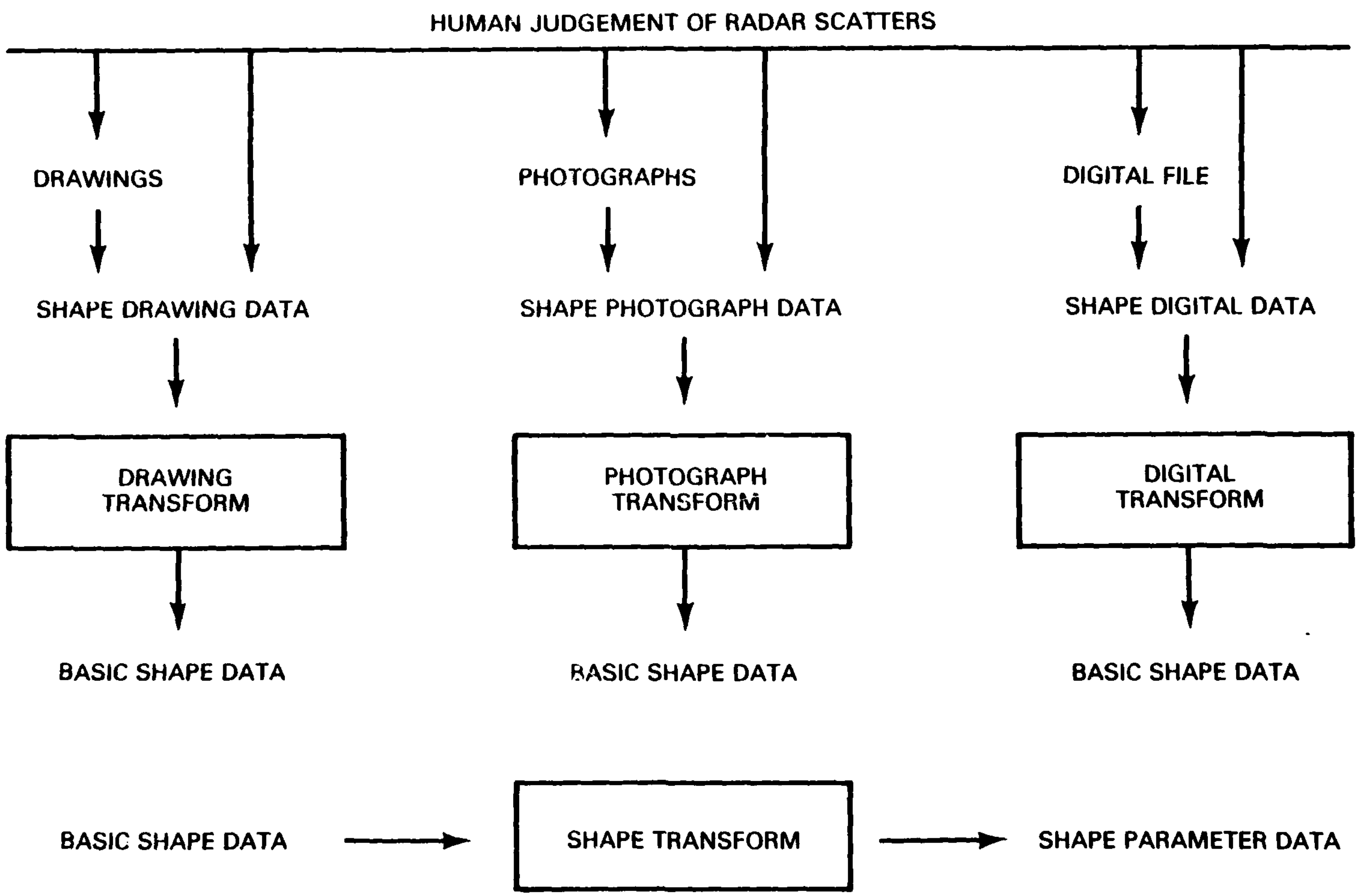

Figure 3.3.5.1-1 SHAPE PARAMETER GENERATOR SIMPLIFIED FUNCTIONAL DIAGRAM

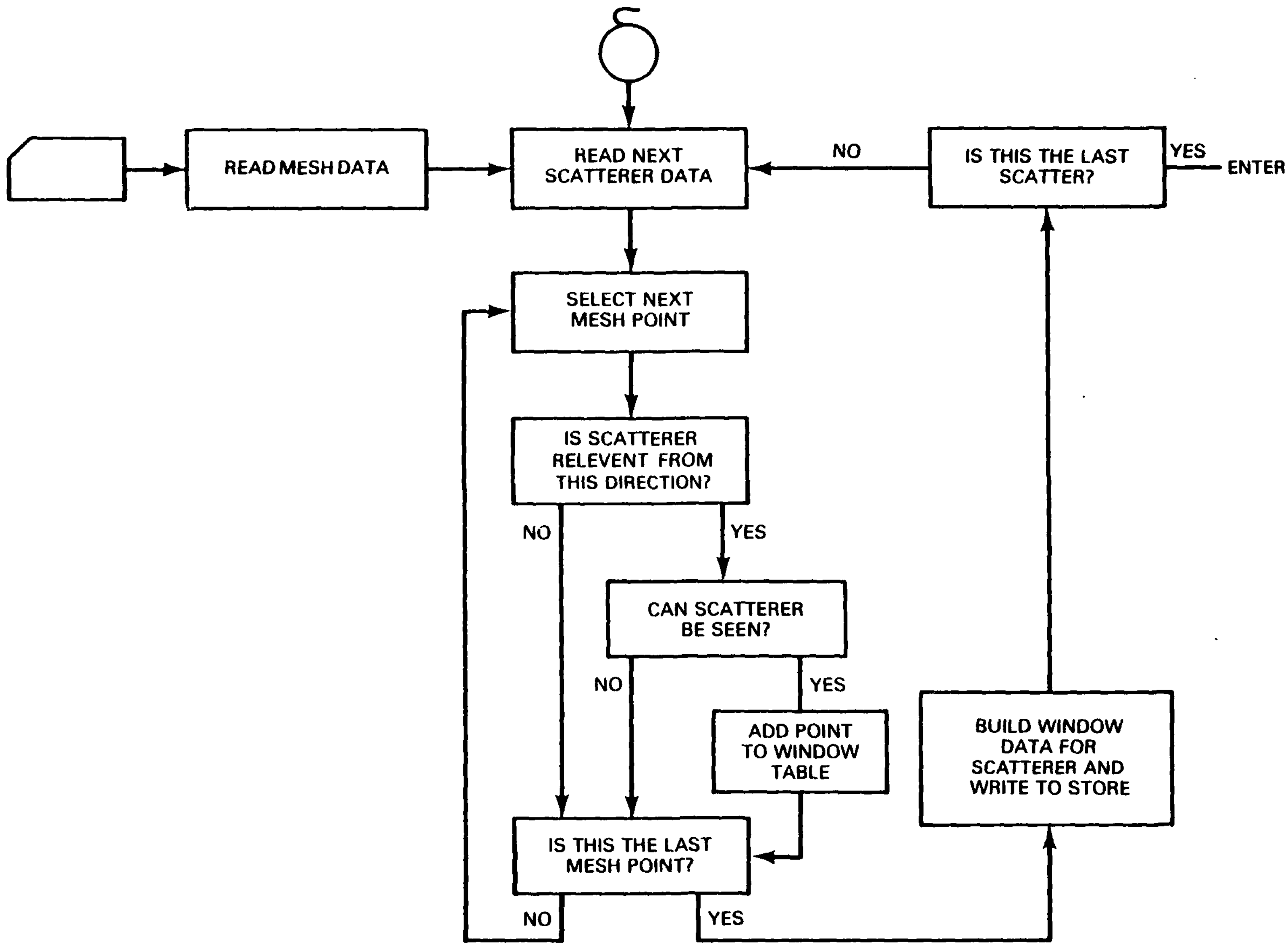

Figure 3.3.5.2-1 SHAPE WINDOW GENERATOR SIMPLIFIED FUNCTIONAL DIAGRAM

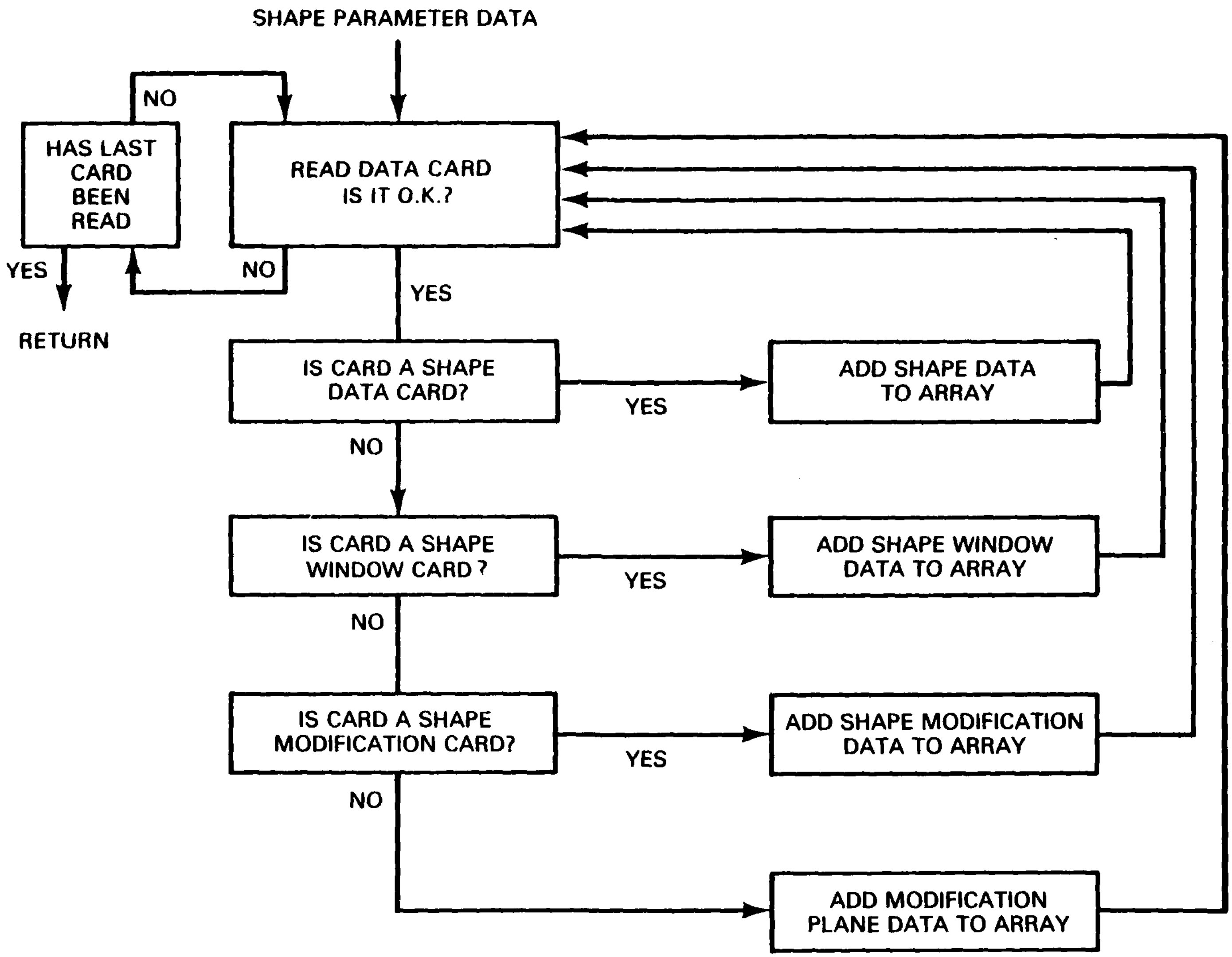

Figure 3.3.5.3-1 MODEL DATA INITIALIZATION SIMPLIFIED FUNCTIONAL DIAGRAM

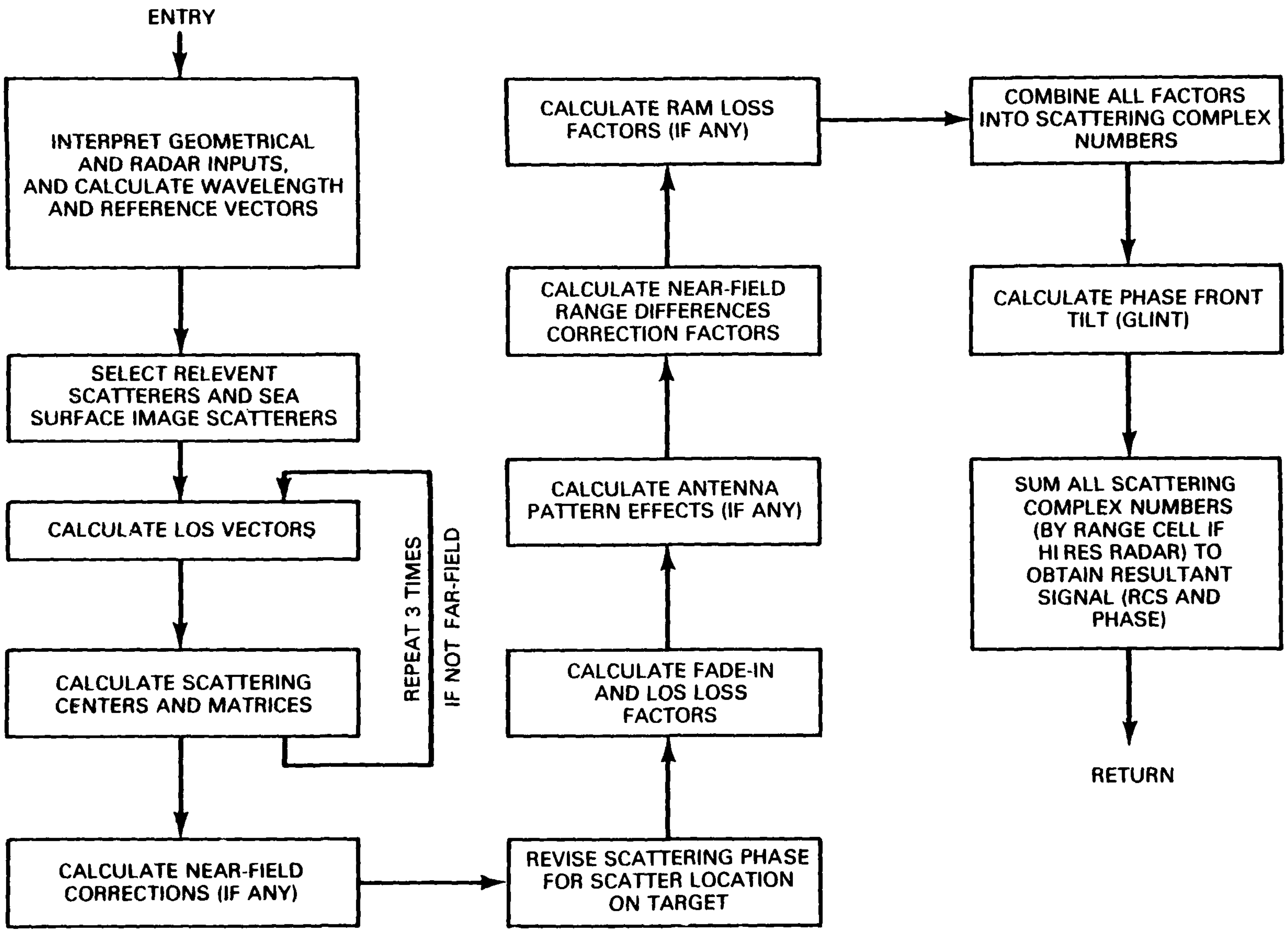

Figure 3.3.5.4-1 TARGET SIGNATURE CALCULATOR SIMPLIFIED FUNCTIONAL DIAGRAM

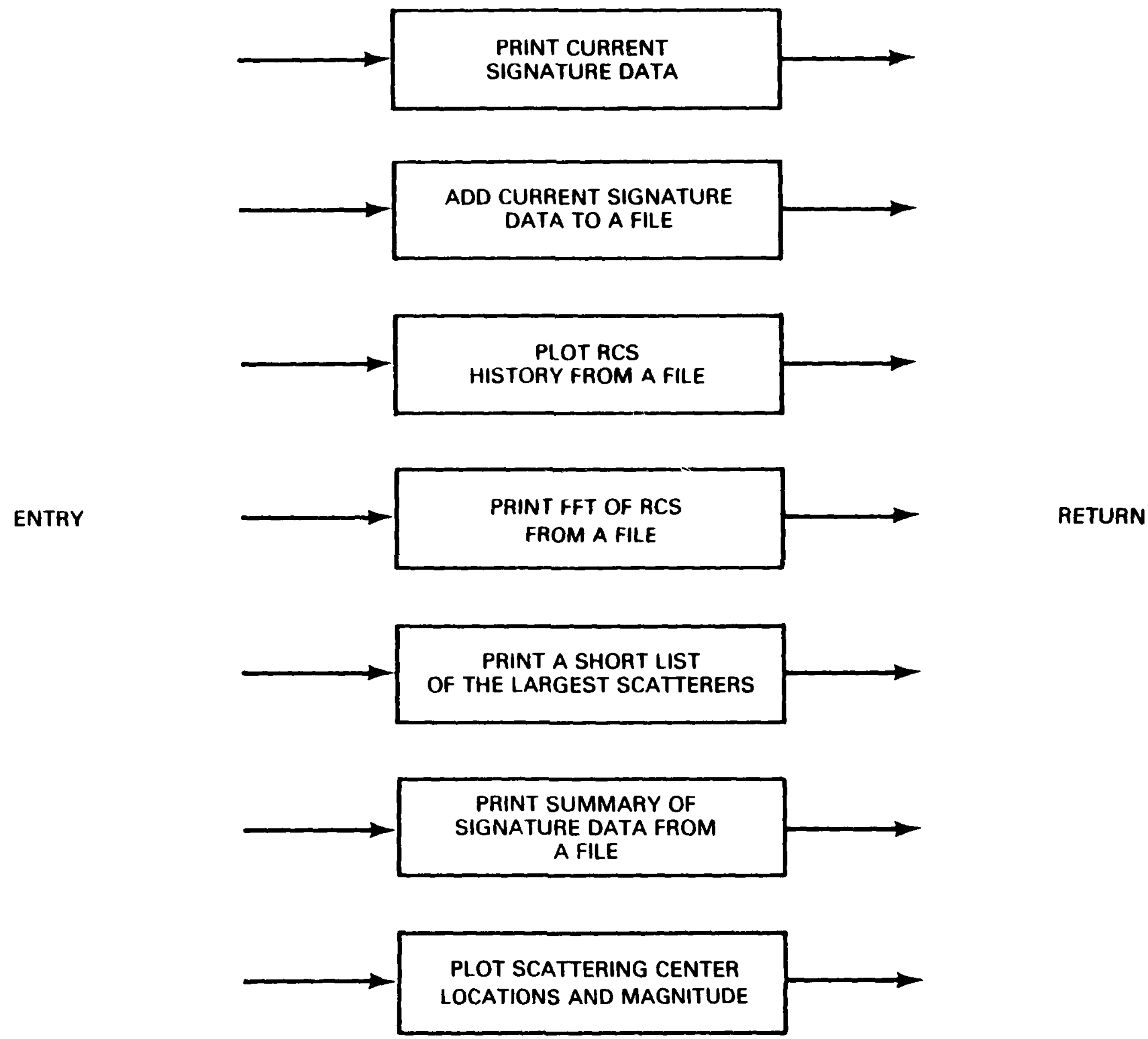

Figure 3.3.5.5-1 SIGNATURE REPORT FORMATTER SIMPLIFIED FUNCTIONAL DIAGRAM

3.3.5.6 Radar Application Drivers

RAD programs control the calling and operation of MDI, TSC and SRF subroutines. The RAD program must (at least once) cause MDI subroutines to read and store the target model data. Then the TSC subroutines must be called with the desired parameters describing the geometrical position and orientation of the transmitter and receiver with respect to the target and the radar characteristics frequency, polarization, range cells, etc. The RAD program may use SRF subroutines to document or store signature data or it may use the data in whatever manner the user programs it to do. See Figure 3.3.5.6-1.

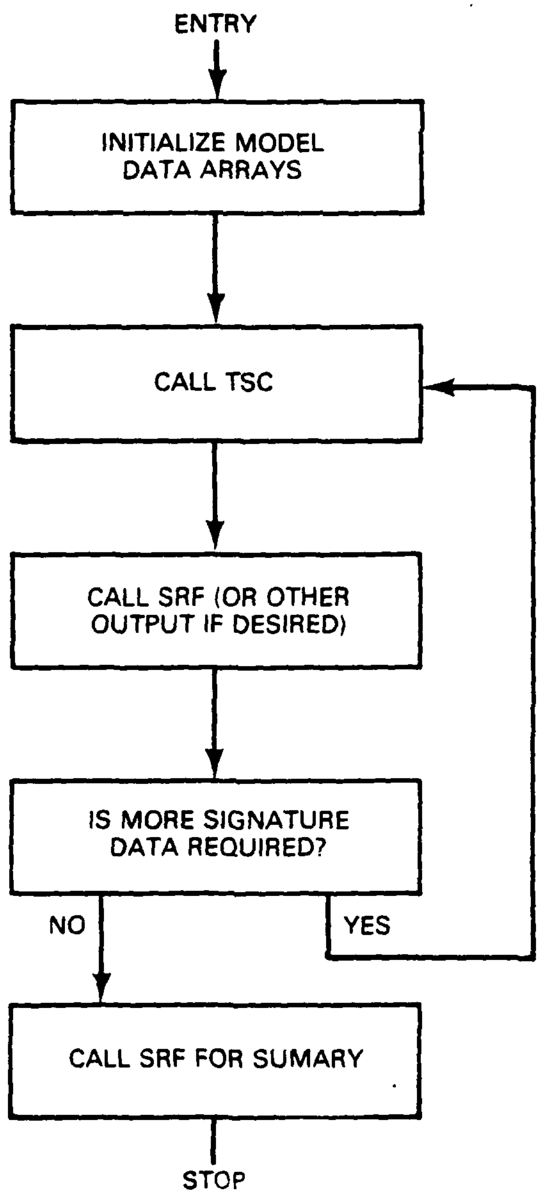

Figure 3.3.5.6-1 RADAR APPLICATION DRIVERS SIMPLIFIED FUNCTIONAL DIAGRAM

3.4 Detailed Functional Requirements

Section 3.4 contains detailed descriptions of each major function. No attempt is made to give the complete mathematical and logical expression for all processes. Each function is specified in performance requirements or suitable procedures.

3.4.1 Shape Parameter Generator (SPG)

Section 3.4.1 describes three programs for alternative ways information about the target is processed into a standard format data file of Basic Shape Data. Then the Shape Transform Program is described which uses the Basic Shape Data to calculate the Shape Parameter Data.

3.4.1.1 Inputs

The inputs to the Drawing Transform and Photograph Transform are similar and will be discussed together. The modeler obtains 2 to 6 orthogonal drawings (or photographs with generally orthogonal views) and identifies all scattering centers of the type implemented in TSC (which see). A large enough set of points (visible on the drawing or photographs) on the geometrical shape which gives rise to the scattering center is selected to completely define the parameters of the geometric shape. This may be from 4 points to 10 points minimum - it is desirable to over define the shape. An arbitrary 2-D coordinate system is set up for each drawing (photograph) and the pairs of coordinates for the same point are found for each drawing (photograph) on which it is indicated (seen). An identifying integer, the shape (scattering center) type and the sets of coordinate pairs for each defining point constitute the input for a single scattering center. Since the coordinate systems used are arbitrary, a reference point and reference

lengths must also be provided as inputs to Drawing (Photograph) Transform program. All this data may be keyed onto cards or directly into a file, but the only efficient way is through the use of a graphics tablet. The input data must be checked for gross errors and the processes must tolerate missing data.

The input for the Digital Transform cannot be defined since no particular digitized target descriptions have been examined yet.

The input for the Shape Transform program is precisely the output of the Drawing, Photograph or Digital Transforms programs, namely the Basic Shape Data.

3.4.1.2 Processing

The purpose of the Drawing, Photograph and Digital Transform programs is to take available target descriptions, through analysis and actions by the modeler, and process the information into a standard format (the Basic Shape Data), with the highest possible accuracy utilizing redundant data wherever available.

In the Drawing Transform two functions are performed sequentially. First, reference data is read which defines the origin and orientation of the target coordinate system, the length, scaling, and boundaries for each drawing. Transformation equations are calculated from each drawing coordinate into the corresponding target coordinate. Second, the drawing coordinates for each point are read, transformed by means of the aforementioned equations, out-of-bounds data thrown away with warning message printed, redundant data averaged and the final data written in the standard Basic Shape Data format.

In the Photograph Transform, all reference data which defines the origin and orientation of the target coorinate system, the length scaling, the boundaries for each drawing, the estimates of camera positions for each photograph, and all coordinate data for all points are read before any processing begins. Then out-of-bounds data is thrown away and an iterative procedure is begun which minimizes the RMS errors of each coordinate measurement (throwing any which exceed error bounds) by perturbing the camera positions. The iteration is stopped if the RMS errors become comparable to the known measurement errors, the camera positions converge or the camera positions diverge. Unless the camera positions diverge (in which case new initial estimates of camera position must be made) the final data is written in the standard Basic Shape Data format.

No processing can be specified for the Digital Transform since the input data is not defined.

In the Shape Transform program, the points given for each shape for which the TSC supports scattering matrix computations are used to calculate a set of parameters which completely describe the shape and any other shapes or planes which may cut off parts of the pure shape. This program, on a shape by shape basis, calculates the parameters in standard form, and the displacement and rotation of the coordinate system of the shape with respect to the target coordinate system. This may be done by direct calculation, or more generally by an iterative process which minimizes the RMS distance of all the data points from the shape while perturbing the coordinate transform and the shape parameters. When the shape parameters are determined and shape modifications - cut off parts - are calculated, they are written on the Shape Parameter Data file along with the shape data.

3.4.1.3 Outputs

There are two output files, the Basic Shape Data file (see Table 3.4.1.3-1) and the Shape Parameter Data (see Table 3.4.1.3-2). The Shape Parameter Data file records may be in any order.

TABLE 3.4.1.3-1 BASIC SHAPE DATA

COLUMN	FORMAT	NAME	DESCRIPTION
1-5	I5	IS	Shape Identification Number
6-7	I2	KS	Shape type
8	A1	KE	Element type
9	I1	IE	Element identification number
10-11	I2	IC	Element card number
12	1X		
13	A1	LA	Reflection type or cross reference flag
14	1X		
15-41	3F9.3	XE	Estimated point coordinates
42-43	2X		
44-70	3F9.3	XR	Estimated coordinates of reflected point
71	A1	J	Reflection
72	1X		
73-76	A4	LT	Name of target
77-80	A4	LV	Name of version

TABLE 3 4.1.3-2 SHAPE PARAMETER DATA

COLUMN	FORMAT	NAME	DESCRIPTION
1-2	A2	KK	≡SD
3	I1	KKI	Unused
4-9	I6	ISI	Shape identification number
10-11	I2	IS	SD card type ≡0
12-19	8X		
20-46	3F9.4	OC	X,Y,Z shape position
47	1X		
48-71	3F8.5	OR	ψ, θ, ϕ shape rotation angles
73-76	A4	NMT	Name of Target
77-80	A4	NMV	Name of Version

Card 1 (Same as Card 0 except for following)

10-11	I2	IS	SD card type ≡ 1
12	1X		
13-15	I2	MTYPE	Shape type
16	1X		
17-18	I2	MST	Shape sub-type
19	1X		
20-46	3F9.4	DIMS	Shape dimensions
47	1X		
48	3F8.5	ANGS	Shape angles

TABLE 3.4.1.3-2 (Continued)

SHAPE MOD DATA

COLUMN	FORMAT	NAME	DESCRIPTION
1-2	A2	KK=SM	
3	I1	KKI	
5-9	I5	ISI	Shape ID
10-11	I2	IS	Card sequence
12-72			Sequence of pairs I/J where
			1 = other shape
			I is
			2 = plane cutoff
			Sign (I) multiplies "distance from surface"
			Negative final result implies "inside"
			or don't use shape. J is shape or mod ID
73-76	A4	NMT	Name of Target
77-80	A4	NMV	Name of Version
		PLANAR CUTOFF MOD DATA	
1-2	A2	KK=MP	
3	I2	KK1	
5-9	I5	ISI	Planar cutoff mod ID
10-11	I2	IS	Not used
12-72			$\cos\alpha$, $\cos\beta$, $\cos\gamma$, ρ
			where
			$x\cos\alpha + y\cos\beta + z\cos\gamma = \rho$
73-76	A4	NMT	Name of Target
77-80	A4	NMV	Name of Version

3.4.1.4 Special Requirement

The Drawing Transform and Shape Transform are required for the initial level of program development. The graphics tablet version of the Drawing Transform is required for the minimum program and the Photograph Transform is required in an enhanced program. The Digital Transform is not now required since it is not known whether there exists enough data of a useful kind to warrant the effort of constructing one (or more) such programs.

3.4.2 Shape Window Generator (SWG)

Section 3.4.2 describes the SWG which takes a complete Shape Parameter Data file for a target and calculates scatterer windows - a set of directions from which a scattering center has clear line-of-sight to the radar and for which the scattering equations in TSC are relevent - for each shape.

3.4.2.1 Inputs

There are two types of inputs to the SWG: (1) Mesh Definition, and (2) Shape Parameter Data. The Mesh Definition contains three kinds of information: (1) how much of the volume about the target is to be searched, (2) how fine a search is to be made, and (3) frequency (see Table 3.4.2.1-1). The mesh parameters are selected by a TSP user who knows the regions of interest about the target. The primary use of the Shape Window Data is in avoiding repetitive computations of relevency and line-of-sight in simulation, so a simulation user must anticipate from which directions a simulation will look at the target in order to specify the mesh needed. The Shape Parameter Data contains descriptions of all the shapes for a target (see paragraph 3.4.1.1 and Table 3.4.1.1-2).

TABLE 3.4.2.1-1 SWG INPUT

COLUMN	FORMAT	NAME	DESCRIPTION
1-10	F10.0	FMHZ	Frequency (MHz)
11-20	F10.0	AMI	Mesh interval (deg)
21-30	F10.0	ANI	Azimuth minimum (deg)
31-40	F10.0	AXI	Azimuth maximum (deg)
41-50	F10.0	ENI	Elevation minimum (deg)
51-60	F10.0	EXI	Elevation maximum (deg)
61-70	F10.0	RNI	Range minimum (m)
71-80	F10.0	RXI	Range maximum (m)

3.4.2.2 Processing

The purpose of the SWG is to write the Shape Window Data file. This file, which is optional, contains information which obviates the need to do relevency and line-of-sight calculations in the TSC. Since this data was calculated at a finite number of mesh points, its use will result in some error in window boundaries. The windows are calculated for monostatic radars so that the boundaries will be in error to the extent that a bistatic angle differs from zero. Applications, such as simulations, which require hundreds or thousands of signatures to be calculated from closely related viewpoints will save substantial computer time by having the Shape Window stored rather than having to calculate it for each signature. This is especially true for targets with a large number of shapes since some of the line-of-sight calculations grow as the square of the number of shapes.

Detailed functional description of mesh point selection and window calculation cannot be given now since the most efficient data structure for window description has not been chosen. Current candidates are (1) "rectangles" in azimuth and elevation defined by four angles, (2) "polygons" with sides (possibly curved) defined by functions of azimuth and elevation, (3) a starting point with a series of unit steps parallel to coordinate axes around boundary in a clockwise sense back to starting point, and (4) a set of "squares" in azimuth and elevation selected from a set generated by dividing each square into four smaller squares, etc. The windows shall be either definite - any direction inside is to be used - or conditional - any direction inside is to be used unless denied by some other window. Windows shall also be either inclusive - valid viewpoints are inside - or exclusive - valid viewpoints are outside.

The functional processes of determining relevence and clear line-of-sight are the same ones used by the TSC and are described in paragraph 3.4.4.2.

3.4.2.3 Outputs

There are three outputs to this program. First, a printout of all inputs and the output Shape Window Data and line printer plots of relevency and clear line-of-sight for selected shapes for the specified mesh; second, a computer readable file fo the Shape Window Data (see Table 3.4.2.3-1); third, a plotter output of mesh point results and window boundaries.

3.4.2.4 Special Requirements

The SWG is required for the minimum level except that (1) only simple windows - inclusive windows with definite exclusive windows - will be implemented, and (2) plotter output will not be implemented. General windows and plotter output are required for the enhanced level program.

3.4.3 Model Data Initialization (MDI)

Section 3.4.3 describes a set of subprograms which when called by a RAD program read data from files and put the data in the computer central memory for use by the TSC.

3.4.3.1 Inputs

The MDI reads two kinds of files: (1) Shape Parameter Data and Shape Window Data, and (2) Radar Absorbing Material Data. The shape data cards are all read by a single subroutine which tests a code in the first two characters of each record to determine the type of data on the card. See tables 3.4.1.3-2

and 3.4.2.3-1 for formats. Two integers are passed as parameters from the RAD indicating two files to be read for the data. If all the data is on one file, then an integer zero is used to indicate the absence of a file. RAM data cards are read from another file if called by the RAD. See Table 3.4.3.1-1 for format definition.

TABLE 3.4.2.3-1 SHAPE WINDOW DATA

The Shape Window Data Formats will be defined when the technique is determined. (See paragraph 3.4.2.2)

RAM DATA

COLUMN	FORMAT	NAME	DESCRIPTION
		CHARACTERISTIC DATA	
1-2	A2	KK	≡RM
3	I1	KKI	Unused
4	1X		
5-80	19A4	KRD	Free form field, blank delimiter 1. Name of RAM 2. Type of data 0 → I,J 1 → VI 2 → VJ 3 → T 3. List of items as indicated above
		SHAPE RAM CROSS REFERENCE DATA	
1-2	A2	KK	≡SR
3	I1	KKI	Unused
4	1X		
5-80	19A4	KRD	Free form field, blank delimiter 1. Name of RAM 2. List of shapes with that kind of RAM

FIGURE 3.4.3.1-1

3.4.3.2 Processing

The purpose of the MDI is to read data on files, interpret it, convert into a form suitable for efficient computation, store it into COMMON block arrays, and print a full, but compact documentation of the model which can be easily skimmed, but which nevertheless provides complete documentation. Also, any initialization which is model dependent is done in MDI.

The Shape Parameter Data is read and processed on a record by record basis - shuffling the records would not affect their interpretation. Each record is checked for correct 4 character target name and 4 character target version. Any unrecognizable card is printed and skipped. When record type code is recognized, the remaining 70 characters are interpreted and stored in the appropriate arrays. Each card type is also counted. When the end-of-data card is read all the input data are printed, a rotation matrix from shape coordinates into target coordinates is calculated and stored, a minimal sphere which contains each shape is calculated and certain shape parameters are set.

The RAM data is read by a free format subroutine - free format is used since these data are likely to be created by hand. There are two types of RAM data: (2) RAM Parameter, and (2) RAM Shape. RAM parameter information contains the name of a type of RAM and an m x n table of attenuation as a function of m frequencies and n bistatic angles. The data for all types of RAM are converted from dB attenuation to voltage attenuation factor for computing efficiency. RAM Shape information consists of lists of shapes which are treated with a particular type of RAM. These tables are stored and used by TSC. All RAM information read is printed as documentation for signature.

3.4.3.3 Outputs

The output of the MDI is the stored arrays and documentation print out. The stored arrays are in a set of COMMON blocks listed in Table 3.4.3.3.

TABLE 3.4.3.3 COMMON BLOCKS INITIALIZED BY MDI

SCATS
CNTRL
NUMBER
SCATW
SCATM
SCATP
TARDAT
SCATC
RAMD

3.4.3.4 Special Requirements

The MDI must be fully implemented in the initial level program.

3.4.4 Target Signature Calculator (TSC)

Section 3.4.4 describes the subroutines which calculate the target signature from the stored model data and the geometrical and radar parameters transferred from the RAD which called the TSC.

3.4.4.1 Inputs

There are two inputs to the TSC: (1) stored model and (2) geometrical and radar parameters. The stored model data is described in table 3.4.3.3-1. The geometrical and radar parameter list is described in table 3.4.4.1-1.

3.4.4.2 Processing

The purpose of the TSC is to calculate the radar return from each scattering center of the target model and add them coherently to obtain a total signature or the signatures in a series of range cells. Each of the major sub-functions will be described in a paragraph below.

The calling geometrical and radar parameters are interpreted and stored locally. The wavelength and wavenumber are calculated and input vectors are normalized. Vectors between target reference and the transmitter and receiver are generated and polarization basis vectors are calculated with respect to the plane of the target reference, transmitter and receiver (and receiver E-vector if necessary).

Each shape is tested for relevancy - i.e. substantial radar return at the frequency and geometry specified - and added to a list of shapes for scattering computation if relevant. If target image caused by sea surface reflections computations are specified by the sea surface reflection control, then the 3 radar

Table 3.4.4.1-1 TSC Calling Parameters

	Input			
1	Radar Frequency (MHZ)			
2	Control Vector	(1)	Transmiter control	
		(2)	Receiver control	
		(3)	Far-field control	
		(4)	Antenna control	
		(5)	Range bin control	
		(6)	Sea surface reflection control	
		(7)	Radar horizon control	
3	Transmitter geometry	3 x 3 matrix	3 x 1	Transmitter position
			3 x 1	Antenna direction
			3 x 1	Polarization E-vector
4	Receiver geometry	3 x 3 matrix	3 x 1	Receiver position
			3 x 1	Antenna direction
			3 x 1	Polarization E-vector
5	Range bin data vector			
6	Sea surface data vector			
7	Radar horizon plane data vector			
	Output			
8	Overall RCS			
9	Overall phase			
10	Overall azimuth glint			
11	Overall elevation glint			
12	Range bin vector of (I,Q) complex numbers			
13	Range bin array of azimuth and elevation glint			

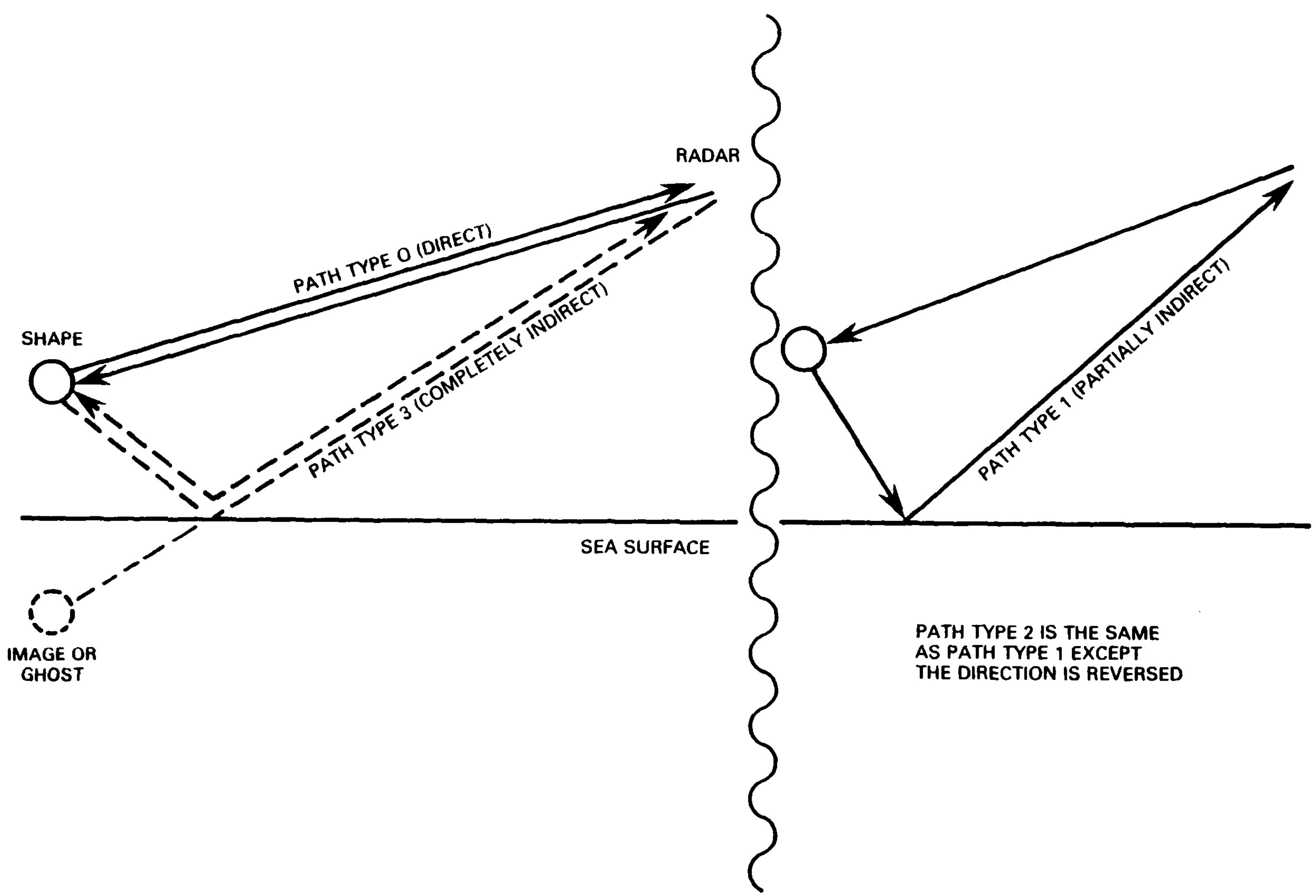

Figure 3.4.4.2-1 SEA SURFACE MULTIPATHS

Table 3.4.4.2-2 List of Shapes (Scatterers)

#	Name	Initial	Minimum	Enhanced
1	Concave Edge	X		
2	Convex Edge	X		
3	Edge Caustic	X		
4	Elliptic Disc	X		
5	Ellipsoid	X		
6	Hyperboloid	X		
7	Cylinder	X		
8	Elliptic Cone	X		
9	Inner Torus	X		
10	Outer Torus	X		
11	Elliptic Tip	X		
12	Rectangular Plate	X		
13	Paraboloid	X		
14	Ogive	X		
15	Point	X		
16	Concave Dihedral (2 reflections)	X	*	
17	Concave Trihedral (3 reflections)	X	*	
18	Straight Edge (convex dihedral)		X	
19	Convex Trihedral (3 plane tip)		X	
20	General Curved Surface Specular			X
21	Cavities			X
22	Antennas			X

*Take care of case where the planes do not extend to the edge or corner.

signal path types (See Figure 3.4.4.2-1) that involve a sea reflection are tested for relevancy and added to relevant shape list if relevant. For each shape in table 3.4.4.2-1, there are criteria determining relevancy. For doubly curved surfaces the criterion is that some point on the surface be normal to the LOS. For singly curved and flat surfaces the LOS must be within the main lobe or first sidelobe of the reflection pattern. Point and edge diffraction scattering is relevant anywhere outside of the shapes producing them. For the case where sea surface multipath is considered, the LOS direction for a reflected path is calculated so that relevancy for a type 3 path is determined. The LOS direction for the type 1 and type 2 paths is the bisector of the LOS directions for type 0 and type 3. If Shape Window Data for a given shape is in an array the above relevancy calculations are not performed and only the window data is used to select the shape for further computation.

An LOS to each selected shape is calculated based on the scattering center position (if already calculated, otherwise the center of a circumscribed sphere about the shape) and the location of the radar. For the bistatic case the LOS stored is the bisector of the LOS's to the transmitter and receiver. For the far field only case the LOS direction for the target reference point is used for all the shapes.

The computation of the scattering matrix and scattering center position are the heart of the TSP. A list of all the types of shapes (scatterers) which are supported for these computations is given in table 3.4.4.2-2. In general, the LOS vector to a shape is transformed from target coordinates into a natural system for each shape. The position of the scattering center is calculated in shape coordinates and then transformed into target coordinates. Then the three complex numbers (the HV element is assumed equal to the VH element) that are the

elements of the scattering matrix are calculated. The above process is done for each relevant shape. For near-field cases a variable number of repetitions of the LOS vector - scattering center calculations are made before the scattering matrix is calculated. This is necessary to eliminate any effect of initially calculating the LOS vectors using an approximation to the actual scattering center position.

Near-field corrections are made to the scattering matrix elements unless the far-field only condition is in effect. Basically, the near-field corrections are a way to "add" the curvature of the radiation field to the curvature of the shape. If the shape is doubly curved a simple loss factor is applied to the matrix. For the partly flat shapes a new near-field scattering matrix is calculated and a transition region defined which makes the scattering matrix elements a continuous function of range from the far-field to the near-field.

Transmitter and receiver polarization E-vectors are projected into a plane orthogonal to the LOS (or bisector of the two LOS's for the bistatic case). Multiplying the 2-D transmitted polarization vector by the scattering matrix of a shape gives the 2-D polarization vector of the scattered wave. The scalar product of the scattered wave vector and the receiver polarization vector gives a complex number characterization fo the return, both amplitude and phase, from a given shape. All the complex signals are calculated here.

Before the individual signals can be added together, the basic phase shift due to reflection (included in the scattering matrix) must be modified to include the path length differences due to the different locations of the scattering centers. Thus, the path length differences between each scattering center and the center of the target coordinater is calculated. Three methods are used:

(1) a far-field method which assumes all incident rays are parallel and all reflected rays are parallel, (2) a far-to-mid-field method and (3) a near-field method based on Pythagorean theorem. The path difference is converted into phase by multiplying by the wavenumber. The phase is used to calculate a complex number magnitude 1.0, which is multiplied by the signal to obtain the signal suitable for coherent addition.

Fading factors are calculated to avoid discontinuous changes in signature as LOS's change. Each selected shape, which does not have LOS window data defined, is paired with every other shape which has LOS blocking ability. First, the LOS's are tested against a sphere circumscribed about the shape being tested for blocking. If the LOS (or two LOS's for bistatic case) does not impinge on the sphere, no blockage is possible and the program goes on to the next potential blocker. If an LOS does impinge on a sphere, further calculations are made to test the segment of the LOS inside the sphere with the particular shape equations. Finally, the scattering center position is checked against any shape modifications to determine how much (if any) the scatterer signal is to be reduced to account for being near (or on) a cutoff part of the shape. All above factors are combined into a "blending" factor.

If the antenna pattern control parameter is greater than 0, antenna gain factors are calculated for each shape signal. The angle from the center of the antenna beam to each scatter is calculated and is supplied to a FORTRAN function GAINR for the receiver antenna (GAINT for the transmitter, if different from the receiver). The one-way power gain with respect to the center of the beam is returned and used to calculate the two-way voltage gain which is stored.

Unless far-field calculations are specified, amplitude correction factors are computed to account for the differences in path lengths from transmitter to scattering center to receiver.

If there are any shapes with RAM, each selected shape is checked for RAM and the appropriate loss factor is calculated as a function of frequency and bistatic angle by table look up and interpolation techniques. All signals are summed to obtain an overall signal for the target. From this sum the RCS and phase are calculated for the overall target.

Glint is generated by calculating an azimuth weight and elevation weight for each selected shape signal. The products of all azimuth weights with the corresponding signal are summed and divided by the unweighted sum (from the RCS computation) to obtain the linear glint in the azimuth direction. The corresponding procedure for the elevation weights gives the glint in the elevation direction.

If the high range resolution control is greater than 0, the program calculates the total signal in every range cell specified. The gain versus range function for each range cell is calculated and used to weight each scatterer signal according to the range differences already calculated. These are summed for each range cell and stored in a vector. Program control is then returned to the RAD. A vector of glint data is similarly calculated.

3.4.4.3 Outputs

The same output is made in two ways. The final signature data is available to the calling RAD through the calling parameters where it can be processed

further. (See table 3.4.4.1-1). The signature data along with many components of the calculation are stored in COMMON blocks for use by the SRF programs. (See table 3.4.4.3-1).

3.4.4.4 Special Requirements

All of the TSC is required for the initial level program except the shapes indicated in table 3.4.4.2-2 and the sea surface multipath signals. Sea surface multipath is required for the minimum level program.

TABLE 3.4.4.3-1 SIGNATURE COMPONENTS COMMON BLOCKS

These COMMON blocks will be determined in the initial level.

3.4.5 Signature Report Formatter (SRF)

Section 3.4.5 describes the SRF which, under the control of a RAD, prints, plots or stores signature data and makes analyses of signature history or components.

3.4.5.1 Inputs

There are two types of inputs to SRF: the control parameters and FORTRAN logical unit numbers of output, and the stored arrays of signature data. Each SRF function has its own controls. Table 3.4.5.1-1 lists the calling parameters for each function. The stored array of signature data is described on Table 3.4.4.1-1.

3.4.5.2 Processing

The purpose of the SRF is to provide the user easy-to-use, correct and neat information and documentation about the signatures which are being generated. The frequency of printouts and their type are under full user control.

RPTSET stores the latest computed RCS and glint into an array. Depending on a control parameter, the data is put in a specified location or an index is set to 1 and the data is put in location 1 or the index is incremented and the data put where the new index indicates. This procedure loads an array for subsequent FFT and/or statistical and summary generation.

RPTFFT does an FFT on glint data stored in the glint array and prints the spectrum.

RPTSUM calculates and prints mean, standard deviation and histograms from stored RCS and glint data.

TABLE 3.4.5.1-1 SWG FUNCTION INPUTS

FUNCTION		PARAMETERS		
NAME	PURPOSE	1	2	3
RPTSET	Stores RCS & Glint sample in arrays	<0 → increment 0 → initialize >0 → element	NA	NA
RPTFFT	Does FFT on stored arrays and prints	print unit #	NA	NA
RPTSUM	Calculates statistics on and line printer plots stored array data	print unit #	NA	NA
RPTPT	Prints signature data and/or writes it to a file	>0 → print heading	>0 → write data to file	print unit #
RPTSS	Sorts all scatters by magnitude and prints up to 8 of the largest ones	print unit #		

RPTPT prints a heading (if commanded) and RCS, phase and glint data for the last signature generated. If instructed, it will also write the data on FORTRAN File 32.

RPTSS sorts by magnitude all the selected shapes of the last signature generated and prints their identification number, type and RCS for up to 8 of the largest ones.

3.4.5.3 Outputs

Output formats for all the functions is given in Tables 3.4.5.3-1 *through* 5.

3.4.5.4 Special Requirements

All the SRF programs are required for the initial level program. New functions should be added as needed.

3.4.6 Radar Application Drivers (RAD)

Section 3.4.6 describes the RAD programs which use the target signature data calculated by the TSC. Only one RAD is furnished as part of the TSP.

3.4.6.1 Inputs

The inputs to the RAD programs are adapted to the function that the user needs. The inputs for the RCS driver are given in Table 3.4.6.1-1.

TABLE 3.4.6.1-1. RCS RAD INPUTS

COLUMNS	FORMAT	DATA
	RADAR CARD	
1	A1	≡R
2-1	F10.0	Range (m)
11-20	F10.0	Frequency (MHz)
30	I1	Polarization 1 → horizontal 2 → vertical 3 → crossed (H-V)
	GEOMETRY CARD	
1	A1	≡G
2-10	F10.0	Elevation angle about target (deg)
11-20	F10.0	Initial aspect angle (deg)
21-30	F10.0	Final aspect angle (deg)
31-40	F10.0	Aspect angle increment (deg)

3.4.6.2 Processing

The purpose of a RAD is simply to use the signature data. Typical uses might be simulation where detailed target signature data is necessary to predict radar and system performance. Another use is just to look at the signature and extract whatever data is desired by hand for some calculation or specification.

The purpose of the RAD described here is to facilitate the iterative modification of a target model in order to reduce the RCS to some level previously specified as desirable. Thus, the program is organzied to compute the RCS for the specified areas about the target. No radar type calculations are necessary, simply elementary ones required to tell the TSC the geometry conditions.

3.4.6.3 Outputs

The SRF printout suffices for this RAD. See Tables 3.4.5.3-1 through 5.

3.4.6.4 Special Requirements

The RAD described above is required for the initial level program. Other RAD, as yet undefined will be required for each kind of data used to test the accuracy of this program.

3.5 Adaptation

The TSP shall be able to store target models containing 1000 shapes with shape modifications and shape window data, and RAM data appropriate for a typical ship target. The TSP shall be able to store 100 selected shapes and calculate all gain factors, weights, etc. The TSP shall be able to handle 256 range cells for high resolution signatures. The TSP shall occupy less than 6500 decimal storage locations in a 32 bit work length computer.

4. QUALITY ASSURANCE PROVISIONS

This section specifies tests/verification requirements, methods of verification, and the necessary tools and facilities to conduct the required tests/verifications.

4.1 General

Subprograms must be tested individually or in functional groups by test programs which exercise all modes of operation with a full range of parameter values. The tests are informal and need no formal documentation. Printouts will be retained along with the test programs for possible future use or debugging.

The whole TSP program must be tested with inputs and model data that proves the program capable of meeting the formal specifications (i.e., those not related to accuracy to the final results). No formal documentation is required.

Accuracy testing of the TSP shall be documented formally be report. Actual measured data of a quality to be used as a reference is rare and must be used for testing whenever funds permit until all types of data (e.g., RCS, glint, high range resolution, SAR) and all frequencies (i.e., 100 MHz to 100 GHz) have been tried.

Acceptance testing of the TSP shall be documented formally be report. It shall consist of two different types of data at two frequencies different by at least a factor of 2.

4.2 Test Requirements

Subprogram (functional) level testing is designed to make sure the program does what it is believed that is was programmed to do. It is intended to find coding errors, logical errors in transforming procedures and equations into algorithms and even errors in the specified procedures and equations. Coding errors are found by hand calculation of all the statements of a program. Logical errors and basic errors are detected by studying the changes in the outputs caused by changes in the inputs. These errors may also show up by causing erroneous states to occur in the computer which the computer can diagnose or causes program shutdown.

Accuracy testing can be no more accurate than the data being used as a reference. Further, even if the data is measured accurately, the conditions (especially the geometrical relationships) may not be known accurately enough to draw any conclusion about the comparison, since radar signatures are extremely geometry dependent. Detailed descriptions and equations for the measurement radar are necessary since a RAD must be written which exactly duplicates the function of the radar. a median error in RCS less than 3 dB is good and less than 5 dB is acceptable when dealing with an overall target or many independent samples of a given scatterer. For comparison purposes the experimental error of the data must be added to the above accuracy specifications.

4.3 Acceptance Test Requirements

The minimum level program and each enhancement functional group shall be acceptance tested for accuracy and reported in formal documentation. Acceptance testing is satisfied when two different types of data for two frequencies at

least a factor of 2 different meet the accuracy requirements given in 4.2. The satisfaction of all other requirements are met informally by inspection of the source code and the printouts of the subprogram testing.

Appendix A - Applicable Documents

See Section 2.

Appendix B - Glossary

E-vector	Electric vector
FFT	Fast Fourier Transform
GTM	Geometric Target Modeler
LOS	Line-Of-Sight
MDI	Model Data Initialization
PPS	Program Performance Specification
RAD	Radar Application Driver
RAM	Radar Absorbing Materials
RCS	Radar Cross Section
RMS	Root-Mean-Square
SAR	Synthetic Aperture Radar
SPG	Shape Parameter Generator
SRF	Signature Report Formatter
SWG	Shape Window Generator
TSC	Target Signature Calculator
TSG	Target Signature Generator
TSP	Target Signature Program
2-D	Two Dimensional